IOP Conference Series: Materials Science and Engineering

PAPER • **OPEN ACCESS**

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To cite this article: M Y Nurain Izzati *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **513** 012005

IOP Conf. Series: Materials Science and Engineering **513** (2019) 012005 doi:10.1088/1757-899X/513/1/012005

Strength and water absorption properties of lightweight concrete brick

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Abstract. This study presented the strength and water absorption properties of lightweight concrete brick containing Expanded Polystyrene (EPS) as the material replacement for sand. EPS has been widely used by the construction industries in the production of lightweight building materials such as wall panel and lightweight concrete blocks. Hence, in this study, EPS has been used as the replacement material in the production of lightweight concrete brick. Replacement of sand by EPS was based on volume. The replacement percentage of EPS was 0%, 20%, 30%, 40% and 50%. The brick properties that have been investigated in this study were density, water absorption and compressive strength. Based on the experimental results, the density and compressive strength of the brick was decreased as the percentage of the replacement increased. Meanwhile, for water absorption properties, it was found that water absorption of the brick was decreased as the percentage of EPS increased. However, the properties obtained has satisfied the requirement where the brick density for lightweight should be less than 1680 kg/m^3 and the strength for load bearing and non-load bearing brick is 11.7 MPa and 3.45 MPa for each individual unit. Meanwhile, for water absorption, the percentage of water absorption of brick should be less than 12% [1,2]. From this study, it was found that, the replacement of sand by EPS give significant impact towards strength and water absorption performance of concrete brick.

1. Introduction

Concrete brick or concrete masonry is well known building materials used in many countries all over the world. In Malaysia, the demand of the concrete brick for housing construction has increase day by day especially in urban area which the population rate is rapidly increased. Due to high demand, the rate of housing prices also increased. The high prices of housing are due to the increasing in the total cost of construction and limitation of raw materials. Hence, the lightweight building materials such as lightweight concrete brick could benefits the economy and society because it will minimise the construction cost in terms of manufacturing, transportation and handling cost. With that it could reduce the housing prices.

One of the most preferable lightweight material is Expanded Polystyrene (EPS). EPS consist of 98% of air and 2% of polystyrene. Due to this, EPS has a very low density which could contribute in the reduction of building materials mass. Abundance of studies has shown that EPS has significantly contribute to the reduction of building materials density [3-10, 12-15, 17-22].

Other than density, rate of water absorption also among significant parameter that should take into consideration in the production of brick. As compared to conventional brick such as clay brick, the rate of water absorption of EPS brick was found to be lower than any other types of conventional bricks. This is due to the non-absorbent characteristic of EPS. High rate of water absorption could affects the performance of concrete in term of strength. For that reason, EPS is preferred as replacement material for improving the water absorption performance of brick. On the other hand, replacement materials by EPS has reduced the strength performance of the building materials [3-5]. However according to the findings in this study, the strength of concrete bricks has achieved the requirement strength for load and non-loading brick where the minimum strength requirement for load and non-load bearing brick are 11.7MPa and 3.45MPa respectively [1,2].

Therefore, in this study, the brick performance was investigated to identify the effects of different percentage of EPS in the concrete brick and also make a comparison with the normal concrete brick.

2. Materials and brick sample preparation

2.1. Materials

In this study, raw materials that have been used for the production of brick are Ordinary Portland Cement (OPC), river sand, Expanded Polystyrene (EPS), tap water and super plasticizer.

2.1.1. Ordinary Portland cement (OPC)

The classification of OPC used in this study is type 1 based on the ASTM C150 [23]. The supplier for this cement is Tasek Corporation Berhad which certified by SIRIM. Cement need to be stored in an air tight container to prevent any moisture contact. The chemical composition of OPC has shown in Table 1.

Table 1. Chemical Composition of OPC.

Chemical Composition	OPC
Silicon Dioxide (SiO_2)	14.6
Aluminium Oxide (Al_2O_3)	3.95
Ferric Oxide (Fe_2O_3)	3.46
Calcium Oxide (CaO)	57.1
Potassium Oxide (K_2O)	0.51
Magnesium Oxide (MgO)	1.62
Sodium Oxide (Na_2O)	-
Sulfur Trioxide (SO_3)	3.43

2.1.2. Fine Aggregates (sand)

Fine aggregates that has been used is river sand. The sieve analysis of sand was conducted in accordance to ASTM C 136 [24]. The sand was dried in the oven at 105^{o}C±5 for 24 hours to ensure the moisture content is constant. Then, the sand was sieved through 2.36 mm sieve opening.

2.1.3. Expanded Polystyrene (EPS)

The size of EPS used in this study was between 1.18 mm to 2.36 mm. EPS used was collected from ST Polyfoam Industries Sdn. Bhd which located in Batu Pahat, Johor.

2.2. Brick sample preparation

For this study, five (5) types of concrete brick samples were prepared which are C, E20, E30, E40 and E50. Each types have different percentage of EPS which are 0%, 20%, 30%, 40% and 50% respectively. Water cement ratio for this study is 0.5 and super plasticizer is 8ml for every 1 kg binder. The curing age for the specimens were at 7 and 28 days. The mix proportion of bricks as shown in Table 2.

Table 2. Mix proportions (kg/m^3).

samples	cement	sand	EPS
C	495.34	1484.72	-
E20	495.34	1186.81	3.98
E30	495.34	1038.19	5.98
E40	495.34	888.88	7.97
E50	495.34	744.44	9.96

*E = EPS, C = control brick

3. Test methods

3.1. Hardened brick density

In determining the density of the brick samples, the test was conducted accordance to BS EN 12390-7 [25] in which determination of the brick mass will be as-received condition. Three samples have been prepared for every mix proportion.

3.2. Compressive strength test

Compressive strength test for this study was conducted according to the ASTM C140-11a [26]. For this test, three brick samples have been prepared for every mix proportion and all the samples tested were full-sized. Any excess moisture or any particles must be removed from the brick surface and the loading plate of the machine before conducting the test. All the brick samples were cured by air curing process in the laboratory until the day of test.

3.3. Water Absorption Test

Water absorption test was conducted in order to determine the percentage of the water absorption by the brick. The test was accordance to the BS 1881: 122 [27]. Initially, the brick samples were dried in the oven at 100^{o}C ± 5^{o}C for 24 hours. The samples were then left to cool down before been immersed in the water tank for another 24 hours. The weight of samples were taken before and after the samples were immersed in the tank in order to determine the percentage of the water absorption. This test was conducted at the curing age of 28 days only.

4. Results and discussion

As mentioned earlier for density and compressive strength, the tests were conducted at the age of 7 and 28 days whilst for water absorption test, the test was conducted at the age of 28 days only. Every types of brick use constant water cement ratio which is 0.5. Following sub sections discuss the outcomes from this study.

4.1. Hardened brick density

Figure 1 shows the density of five (5) types of concrete brick. Based on the figure it can be seen that, density of the brick samples decreased as the percentages of the EPS increased. At 7 days, density of control brick (C) is 2150 kg/m^3 meanwhile the density of E20, E30, E40 and E50 are 1864 kg/m^3, 1778.57 kg/m^3, 1692.86 kg/m^3, and 1457.14 kg/m^3 respectively. This shows that, 20% of EPS has reduced the brick density up to 13%. For E30, E40, and E50 it was found that the brick density was

decreased from 17.3% up to 32.2% from normal brick. This has verified that, EPS has significantly reduce the brick density due to its characteristic which is low in density. Similar finding was found by Mulla & Shelake [8] where replacement of EPS in the concrete mix has reduced the brick density about 29% to 40% from the conventional brick. Meanwhile, according to latest research by Tayal et al [21], where 30% of EPS has reduced the concrete density up to 37% from normal concrete.

The reduction of the brick density continuous to decrease as the percentage of replacement materials increased. According to ASTM C90 [1], density for lightweight masonry brick should be less that 1680 kg/m^3. Therefore, from Figure 1, it can be observed that density of brick E40 and E50 has achieved the lightweight density as stated in the ASTM C90 [1].

Besides percentage of materials replacement, brick age similarly contribute in the reduction of density. As can be seen, density of brick at 28 days is slightly lower than brick density at 7 days. For example, for brick sample E20 the density at 7 days is 1864 kg/m^3 whilst the density at 28 days is 1850 kg/m^3. From this it can be seen that, the brick density was reduced about 0.8% from day 7 to day 28. Another example, for brick E50 the density at 7 days is 1457.14 kg/m^3 and the density at 28 days is 1435.71 kg/m^3. The reduction of brick density was about 1.5%. Possibly, the reduction of brick density was due to loss of water content throughout the air curing process.

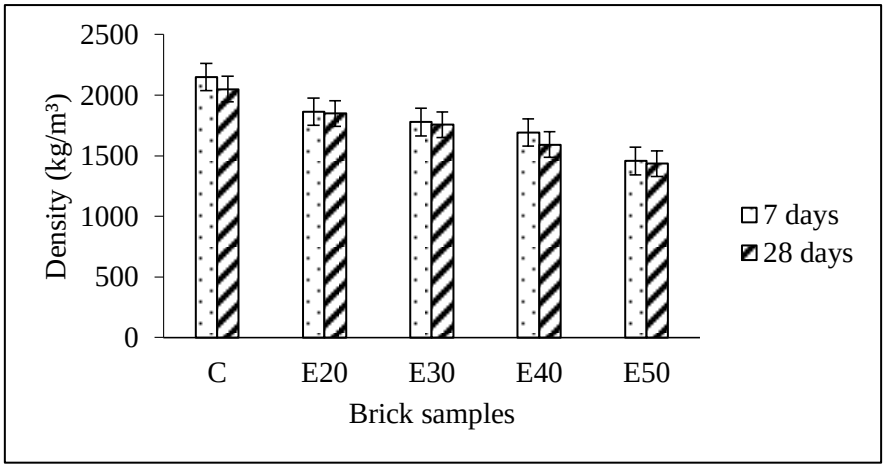

Figure 1. Hardened brick density of bricks.

4.2. Compressive strength

Figure 2 shows compressive strength of each types of brick. Based on figure shown, it can be seen that, overall strength of the brick decrease as the percentage of EPS increase. For instance, the brick strength of control brick (C) at 7 days is 25. 7 MPa whilst for E20, E30, E40 and E50 the brick strength were 21 MPa, 13.5 MPa, 11.2 MPa and 9.3 MPa respectively. It can be seen that, 50% of EPS has reduced the brick strength up to 64% from the normal brick. The same observation was found by Tamut et al [6] where in their studies the replacement of aggregates by EPS was 5%, 10%, 15%, 20%, 25% and 30%. According to their findings, the compressive strength of the concrete was reduced up to 55% as compared to the normal concrete. This has shown that, the replacement of sand by EPS also significantly reduced the brick strength. The great reduction in strength is due to the characteristic of EPS with is extremely low in strength which is almost zero in strength.

Meanwhile, for brick samples at 28 days, it can be observed that, all types of brick have higher strength as compared to the earlier strength. This was due to hydration process by the cement paste of brick at the later age.

Although EPS has greatly reduced the brick strength, yet it was found that the brick strength of 50% EPS is 13.5 MPa which is above the minimum requirement for load and non-load bearing brick as stated in ASTM C90 and ASTM C129 [1,2].

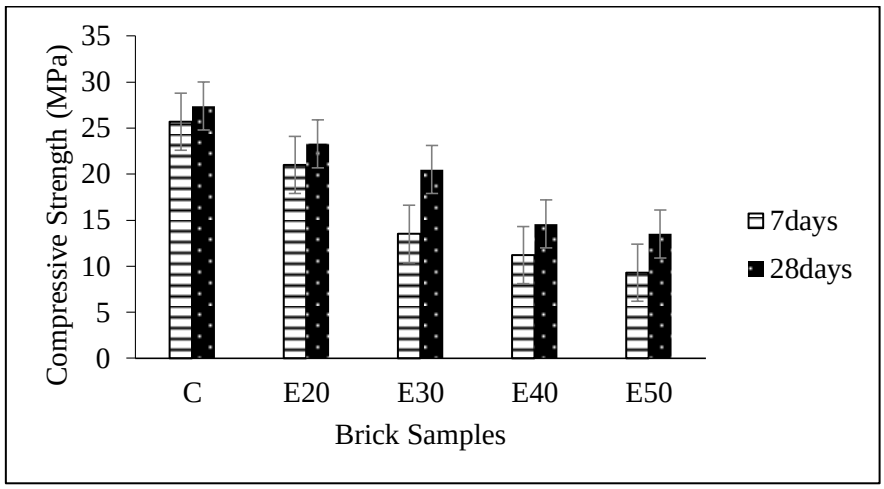

Figure 2. Compressive strength of bricks.

4.3. Water Absorption

Figure 3 shows the percentage of water absorption for each different types of brick. As can be seen, water absorption of control brick (C) is 11.23%. The percentage of water absorption of brick decrease as the percentage of EPS increase. Brick samples with EPS had lower percentage of water absorption comparing to control brick (C). For instance, E20 has water absorption of 6.95% which is 4.28% less than C. Percentage of water absorption continuous to decrease where water absorption of brick samples E30, E40 and E50 are 6.1%, 5.82% and 4.37% respectively. The same observation was found by Babu et al [19] where in their study on the effect of moisture migration of concrete containing EPS. They have found that, concrete containing EPS show lower water absorption comparing to normal concrete. This can be conclude that, the reduction of percentage of water absorption with the increment of EPS was due to non-absorbent characteristic of EPS.

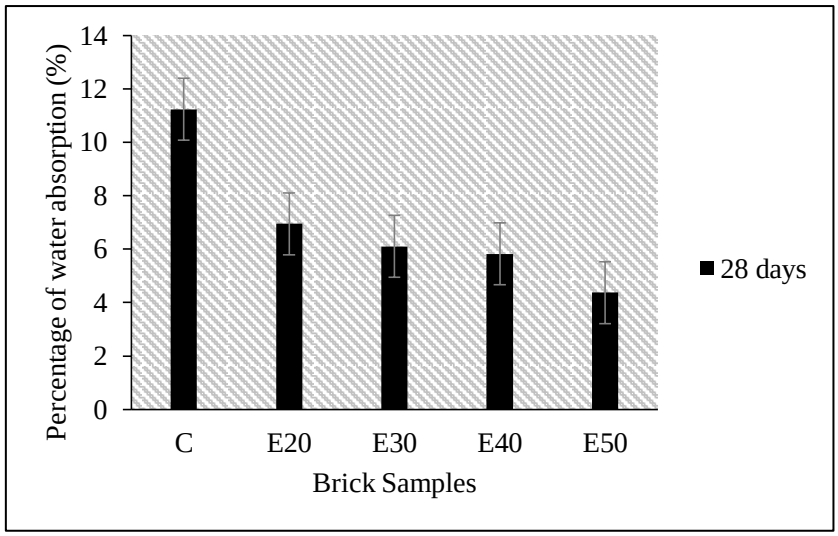

Figure 3. Percentage of water absorption of bricks.

5. Conclusion

- For density, it can be seen that EPS has significantly reduced the brick density where, as the percentage of replacement materials increase, the density of the brick decrease. In this study, maximum replacement of materials is 50% of EPS has reduced the density of the brick up to 30% from normal brick. This indicates that, EPS is a highly potential materials for the production of lightweight concrete brick.
- Strength properties of brick also highly affected by the existing of EPS in the brick. Based on the findings, generally the EPS has reduced the brick strength. However, it was found that, maximum replacement of EPS which is 50% has strength of 13.5 MPa which is above the minimum requirement for load and non-load bearing brick as stated in ASTM C90 [1] and ASTM C129 [2]. This has proven that, the replacement of EPS did not compromise the brick strength of brick.
- For water absorption properties, the findings shows that, as the replacement of EPS increase, the percentage of water absorption decrease. This is believed due to characteristic of EPS which is non-absorbent that helps in reduction of water absorption.

Acknowledgement
The authors gratefully acknowledge the Universiti Tun Hussein Onn Malaysia and Ministry of Higher Education for providing the financial support through the Fundamental Research Grant Scheme (FRGS), Vot 1618 and Postgraduate Research Grant (GPPS), Vot U77.

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